

Use of the Polarized Radiance Distribution Camera System in the RADYO Program

Kenneth J. Voss

Physics Department, University of Miami

Coral Gables, FL 33124

phone: (305) 284-2323 ext 2 fax: (305) 284-4222 email: voss@physics.miami.edu

Award Number: N000140610720

<http://optics.physics.miami.edu>

LONG-TERM GOALS

My work involves experimentally investigating the interrelationships and variability of optical properties in the ocean and atmosphere. My goal is to define the variability of the optical properties, particularly those dealing with light scattering, and to improve the prediction capabilities of image and radiative transfer models used in the ocean. My near term ocean optics objectives have been: 1) to improve the measurement capability of measuring the in-water and above-water spectral radiance distribution and extending this capability to polarization, 2) to investigate the variability of the Point Spread Function (PSF) as it relates to the imaging properties of the ocean, and 3) to improve the characterization of the Bi-directional Reflectance Distribution Function (BRDF) of benthic surfaces in the ocean, and 4) to understand the capabilities and limitations of using radiative transfer to model the BRDF of particulate surfaces.

OBJECTIVES

The major objective of this research is to understand the downwelling spectral polarized radiance distribution, in the near surface of the ocean.

APPROACH

We have built, with ONR support (through the DURIP program) a camera system capable of measuring the polarization state of the downwelling radiance distribution. This instrument follows in the footsteps of other instruments we have developed (Voss and Liu, 1997) and uses a combination of 3-4 images of the radiance distribution to form this polarized radiance distribution. Because the downwelling radiance distribution is very dynamic, we need to have a system that will quickly make these images as matched as possible, so this required a completely new design.

The system we have designed uses 4 fisheye camera lenses with coherent fiber bundles behind each image. Each fisheye will have a polarizer in a different orientation. After the image is in the coherent fiber bundle, these bundles will be brought together and imaged on a CCD array camera, through a filter changer (for spectral information). Thus in a single image we will have 4 separate fisheye images of the scene, each with different polarization information. The work in this proposal is to characterize this instrument, and use it in the RadYO program.

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 2010		2. REPORT TYPE		3. DATES COVERED 00-00-2010 to 00-00-2010	
4. TITLE AND SUBTITLE Use of the Polarized Radiance Distribution Camera System in the RADYO Program				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Miami, Physics Department, Coral Gables, FL, 33124				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED

While on the two research cruises of the RadYO program, we measured the downwelling spectral polarized radiance distribution, both in the water (using DPOL) and above the surface (with our sky camera system, developed for this project), upwelling spectral polarized radiance distribution (with DPOL), and the aerosol optical depth (using Microtops sunphotometers).

During the past year we have been working on improving our characterization and calibration of our DPOL instrument. In particular we have been working on calibrating and characterizing the fourth lens of our system, which allows the determination of the 4th Stokes component, which specifies the circular polarization. We have also reduced the field data collected during these two field experiments, in Santa Barbara Channel and off of the Island of Hawaii. Both of these field trips were done on the research platform R/P Flip in collaboration with other researchers doing both optical measurements and surface wave field measurements. While working on the data from the first field experiment we found that we needed to take several steps to improve the system. These were done and the system was recharacterized. We are now in the stage of analyzing the reduced data.

RESULTS

First for the easy part, all of the aerosol optical depth measurements, in both cruises have been reduced and are available both from our lab and also from the NASA Marine Aerosol Network (http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html).

We have also reduced the polarized sky radiance distribution data and the in-water data from the Santa Barbara Channel experiment and the Hawaii experiment. These data are posted on our website: <http://www.physics.miami.edu/optics/mainpage.htm>, and preliminary presentations have been given at the RaDYO data meetings, an ONR program review, and at the 2010 AGU Ocean science meeting.

To give examples of some of the data, we show an example sky and in-water radiance distribution at 520 nm. Figure 1 shows the sky and in-water radiance at 520 nm. Figure 2 shows the Q and U Stokes parameters in the sky and in-water, while Figure 3 shows the degree of polarization in the sky and in-water radiance distribution.

IMPACT/APPLICATIONS

The goal of the overall RadYO program is to understand how the radiance distribution is modified in the near surface, and what factors are important to this modification. Our work is showing how the near surface polarized radiance distribution is modified as it is transmitted through the air-sea interface and then into the water column.

RELATED PROJECTS

This project is part of the overall ONR RadYO program. We also have had DURIP support to build the instrument, fundamental to this work. Our work on the polarized radiance distribution is also related to our efforts with NASA funding to look at both the upwelling radiance distribution and the polarized upwelling radiance distribution.

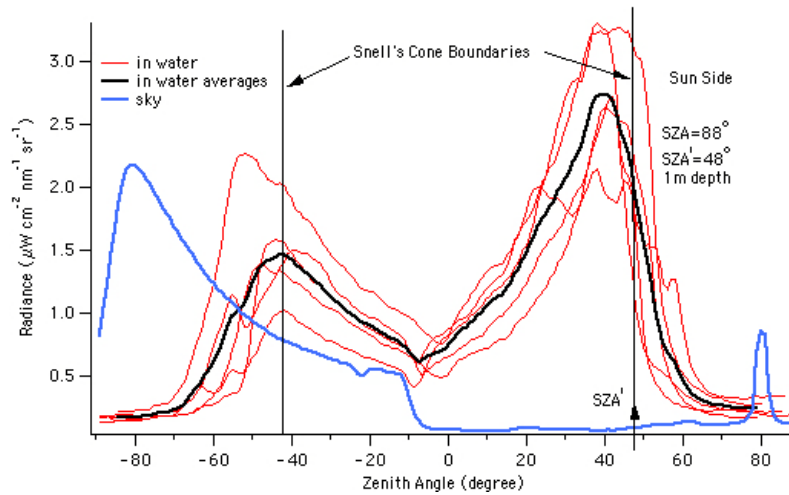
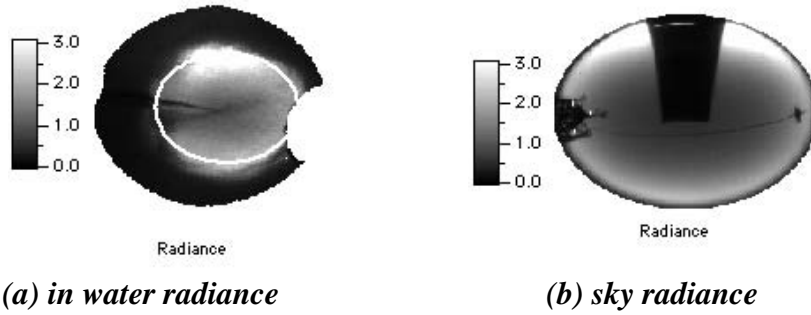


Figure 1. (a) in-water radiance at 1 meter, at 520nm. Snell's cone is clearly seen almost within the theoretical Snell's boundary (white circle). On the left within the circle the two dark lines are images of the FLIP and the wire supporting the camera. The sun is at the top of the circle. (b) Corresponding sky radiance. On the left we can see the top portion of the FLIP. The dark rectangular part on the top is the occulter used to block the sun. The horizontal line across the middle of the image is the line supporting the boom of the FLIP. (c) Downwelling radiance in the solar principal plane. Zero is zenith and positive is towards sun. We can see the two peaks in the in-water radiance around the edges of the Snell's cone, one towards sun and the other opposite to it. The sky radiance has the occulter, so the sun side of the image is suppressed.

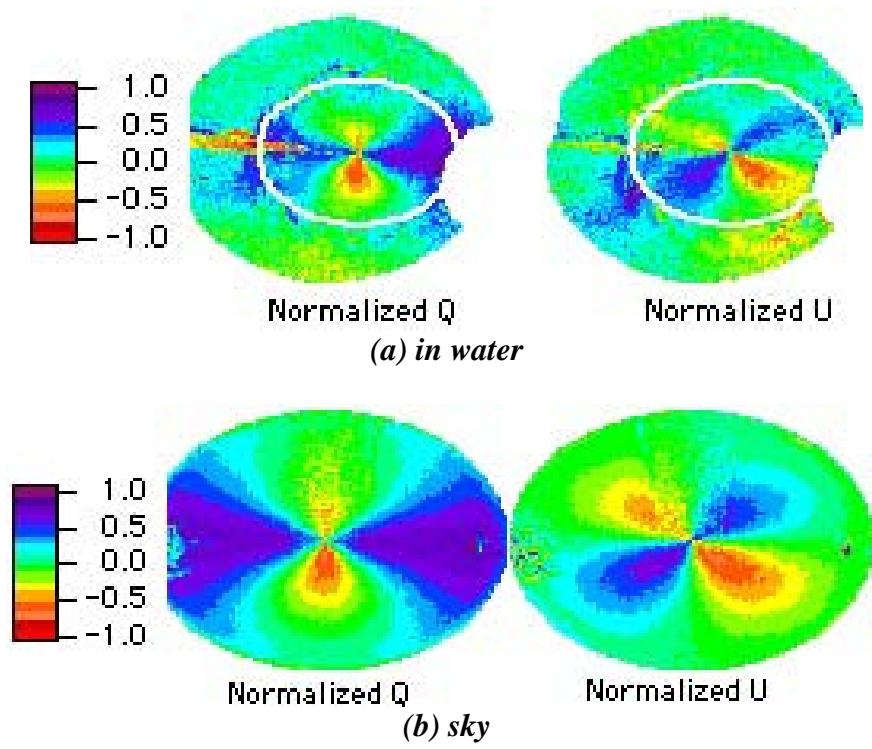


Figure 2. Normalized Q and U vectors in water (a) and in air (b). In both cases the minimum of normalized Q and U are at 45 degree to each other and the minimum Q lies opposite to the solar position along the solar principal axis.

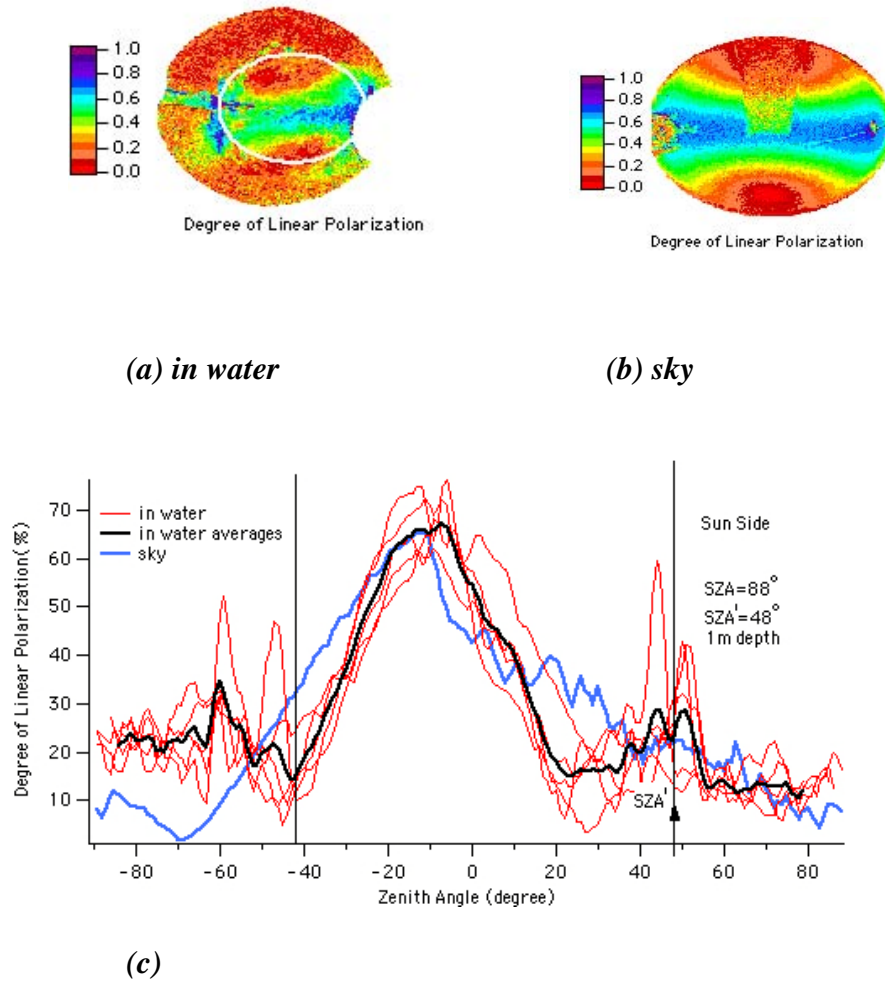


Figure 3.(a) and (b) in water (1 m depth) and sky polarization pattern for 520nm wavelength. (c) Variation of the degree of (linear) polarization with zenith angle along the solar principal plane. The sky and in water curves are similar in nature and both of them have almost the same DOP (about 65 %) which implies that the refracted sky light is the dominant source of polarization.

REFERENCES

K. J. Voss and Y. Liu, “Polarized radiance distribution measurements of skylight: I. system description and characterization”, 1997, *Applied Optics*, **36** :6083-6094.

PUBLICATIONS

K. J. Voss and N. Souaidia, “POLRADS: polarization radiance distribution measurement system”, *Optics Express*, **18**, 19672-19680 (2010).